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Development of sitting ability, assessment of children with a motor handicap and prescription of appropriate seating systems

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Abstract

The prescription of appropriate seating for children and young adults with a motor handicap is a complex issue requiring a clear identification of the child's physical ability in all postures. Recent work by Pountney *et al.* (1990) has shown how the development of lying ability is linked to sitting ability. This emphasises the importance of the total approach to assessment and prescription of seating systems and of not isolating seating needs from other postural considerations.

This article summarises the work undertaken in recent years at Chailey Heritage to improve knowledge about prescriptive, adaptive seating for children with a motor handicap. The results are being increasingly applied throughout the United Kingdom.

Postural stabilisation

Postural stabilisation is a vital prerequisite to the establishment of a functional sitting posture. Able-bodied people have the postural ability to compensate for the inadequacies of the many seats that are in use and are able to change position to avoid discomfort or to improve function whilst in the sitting position.

People with physical disabilities who lack postural ability therefore need seating which is far superior to that used by the able-bodied population. The seating has to compensate for the lack of postural stability whilst also enhancing the functional and postural ability that each individual has. It will be recognised that every person with a disability will have a very individual need and great demands are placed on the designers and producers of seating systems in order that each individual reaches his or her full potential in terms of postural and functional ability.

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It is accepted that very few children with physical disabilities receive all the therapy time that each requires. It is very important therefore that therapeutic principles are carried over between therapy sessions if the valuable gains achieved during therapy are not to be lost. Indeed, equipment used by the children should be seen as part of their therapy. All prescribed equipment must provide the required postural control, postural stabilisation and the postural accommodation compatible with the programme and goals of treatment and management for that child.

It is convenient to divide the biomechanics and the equipment which achieves the biomechanical support into two categories: Posture Accommodation and Posture Stabilisation.

Posture accommodation involves the accommodation and support of an existing posture. This is usually the approach used when the child has a fixed deformity or a progressive deformity or is at risk of tissue trauma from anaesthetic skin. The primary consideration is not the application of biomechanical principles to achieve significant improvements but to provide comfort, to protect the child from damage such as tissue trauma or from fractures as in the case of osteogenesis imperfecta and to maintain maximum functional ability in the case of conditions such as Lesch Nyhan syndrome where self protection is also a consideration. Posture accommodation is usually the primary consideration when there is little potential for long term improvement. The physical problems associated with the advanced stages of muscular dystrophy and Lesch Nyhan syndrome together with those associated with severe cases of spinal muscular atrophy and spina bifida are examples of when posture accommodation is considered as a priority. Quite often, the initial posture presented is not greatly modified by the equipment produced but the child's arms may be

relieved of weight-bearing and hence function is improved, head control may be improved or at least maintained and the child can be protected from himself and the environment. In many cases, the equipment will be a complex compromise perhaps consisting of a spinal orthosis with a built-in, inconspicuous headrest which the child uses in conjunction with special cushioning and thoracic pads or perhaps a very carefully and precisely made moulded seating system or Matrix seat. The principles of posture stabilisation described below need to be considered in this type of seating in order to ensure that maximum function and comfort can be achieved but they will not be the priority in the final design.

Posture stabilisation involves the use of appropriate biomechanical principles to take a pro-active approach to the production of seating systems to provide stabilisation and control compatible with therapy programmes and which facilitate and improve function in both the short term and the long term. Seating for posture stabilisation thereby achieves both immediate and long term improvements in postural ability. It is essential that each child is carefully assessed to determine his level of ability from which the prescriptive needs can be clearly defined. It is equally important to review these needs constantly during the use of the equipment in order that it may be adjusted to maintain the gains and achieve further improvements.

Without a stable platform from which to operate, no one is able to function properly or to their maximum ability and full concentration is required to prevent sliding or falling. Able-bodied people need only to walk on ice or sit on a greasy pole to experience this! For seating systems to be of benefit they must, therefore, provide postural stability and follow biomechanical and therapeutic principles to optimise function and potential for improvement. They must also meet orthopaedic requirements and be easy to use. It is often difficult to meet all of these objectives but current efforts in design and development are improving on solutions to these problems. It should be recognised that all equipment provided for all children is inevitably a compromise. It is therefore essential that the parents, carers, teachers, treating professionals and others who need to know are involved in the assessment and prescription process in order that all needs are clearly identified. It is then possible to reach a satisfactory compromise where the objectives are understood and any limitations of use are accepted.

It is extremely important that the performance of a seating system is measured. The performance should be measured in terms of the short term and long term improvements in postural ability achieved by the child. If the correct biomechanical principles have been adopted, then improvements should be possible or at least abilities should be maintained through growth spurts or other periods of difficulty. If deterioration in ability is observed then attention should be directed to both the seating system and its adjustment and to the child's lying ability. The importance of correct and frequent adjustment to seatings and the relevance of the child's lying ability is addressed later.

The biomechanics of the upright sitting posture

There are many "sitting" postures that may be adopted but the one that most frequently comes to mind and around which most of our activities and furniture are designed is the "upright" sitting posture. This is defined as one of balance in which the hips and knees are flexed at 90° and the ankles are in the plantargrade position or 0° of flexion. The biomechanics described here will be related to achieving this posture.

When sitting in a chair it is important that as much contact as possible is made with the chair's support surface to achieve comfort through distribution of supporting forces and to achieve stability through the largest base of support. An upright, right-angled chair cannot, therefore, provide an upright posture without some degree of discomfort, instability or a great deal of postural muscle activity (Fig. 1). The discomfort

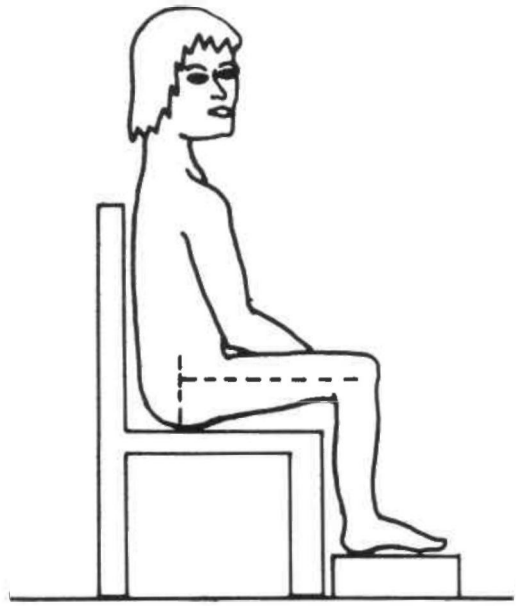


Fig. 1. Upright posture with pelvis in neutral position, hips and knees at 90° of flexion and ankles at 0° showing incompatibility of upright right angled chair.

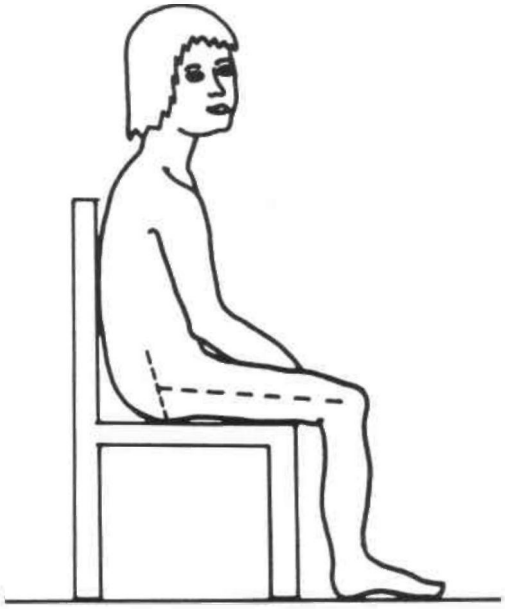


Fig. 2. Slumped, "chin poking" posture normally adopted on upright, right angled chair.

will arise from support only being provided to the ischial tuberosities when the femurs are horizontal which will also lead to instability if this is the only area of contact for support. The feet need to be supported at the right height to keep the femurs horizontal. This may require resting on tip-toes and postural ability will be required to maintain the pelvis in the neutral plane, with the trunk upright and also to stay in position on the chair. The posture most likely to be adopted on a flat, right-angled chair, is one with the thighs in contact with the seat surface and hence the femurs sloping forwards and the pelvis posteriorly tilted. There will be loss of lumbar lordosis and an accentuation of the thoracic kyphosis and cervical lordosis leading to a slumped, "chin poking" posture (Fig. 2). This is not a stable posture and frequent repositioning is required to prevent falling. Discomfort will be a continuous feature of any posture on this type of chair.

The first objective is to provide appropriate support and control for the pelvis and thighs to hold the femurs horizontally and provide a stable, horizontal platform for the ischial tuberosities. There are different ways of achieving this and the easiest and most successful is the ramped cushion (Mulcahy and Pountney, 1987). Made from the correct grade of high resiliance, combustion modified foam, the flat surface provides stability for the pelvis and the 15° ramp starting just anteriorly of the gluteal crease provides support for the thigh to maintain the femur horizontal. The 15° angle suits most anatomical shapes but may need to be varied to meet specific needs. In general, larger people require a larger angle but this may lead to difficulties in getting in and out of the seat. To ensure that the cushion will work properly the feet must be supported at the correct height to maintain and ankles at 0°, the knees at 90° and the femurs supported horizontally. This may be achieved by adjusting footrests or by adjusting the height of the chair if the feet are on the ground.

With this provision, the pelvis is still not controlled and postural ability is required to maintain the neutral pelvis position and the upright posture. It should be noted that the natural, upright curvature of the spine can only be adopted when the pelvis is in the neutral or slightly anteriorly tilted position. This is most easily achieved in the standing position. When sitting, tight hamstrings and general relaxation or lack of tone or control lead to posterior tilting of the pelvis which in turn leads to flattening of the lumbar lordosis and accentuation of the thoracic kyphosis and cervical lordosis. The conventional correction for this posture has been the introduction of lumbar support to reintroduce the lumbar curve but this has disadvantages.

Firstly, children who have not yet developed the ability to achieve independent sitting will probably not have developed a lumbar lordosis. Introduction of a lumbar curve with lumbar support is therefore inappropriate and can result

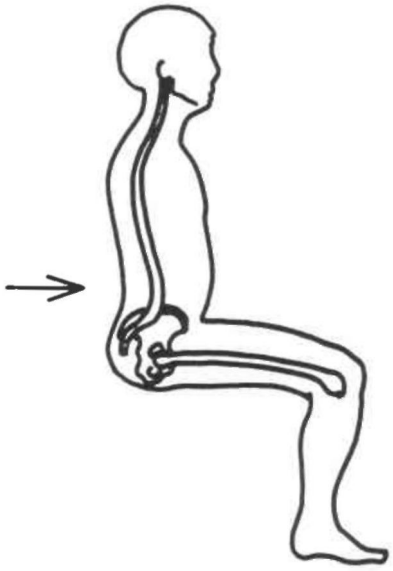


Fig. 3. Lumbar spine being used as a lever by a lumbar support to bring the pelvis to the neutral position to restore a lumbar lordosis.

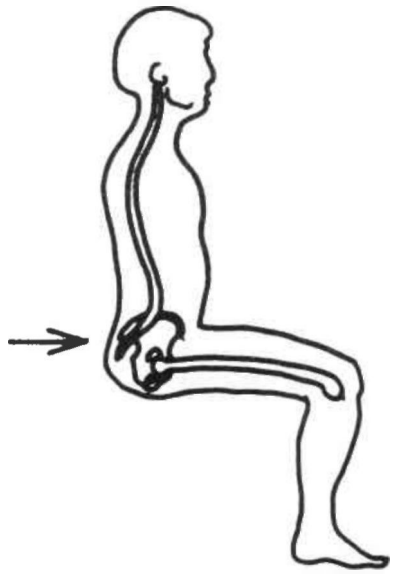


Fig. 4. Force applied to the pelvis by a sacral pad to bring the pelvis to the neutral position thus restoring or facilitating a lumbar lordosis.

in the child extending against the lumbar pad or being pushed into a flexed posture by it.

Secondly, the lumbar curve can only exist if the pelvis is in the neutral plane and a lumbar pad alone, therefore, uses the lumbar spine as a lever to bring the pelvis to the neutral plane (Fig. 3). This can cause high shear forces on the L5/S1 joint and discomfort can result.

A more appropriate method of achieving the correct spinal curvature is to apply a force directly to the pelvis (Fig. 4) to bring it to the neutral plane and this is achieved with the sacral pad (Mulcahy and Pountney, 1986). The sacral pad extends the full width of the pelvis, it is curved in the horizontal plane to provide comfort when applying a force to the pelvis and it extends no higher than the L5/S1 joint. That is, it acts on the full width of the pelvis over the length of the sacral spine, hence its name. The thickness of the pad is chosen to compensate for the different anteroposterior dimension of the trunk and the pelvis, typically 18mm to 36mm but this may vary according to the material of the backrest support and any deformity that may be present. The upright posture and natural curvature of the spine are now attainable but the biomechanical system is not yet complete.

When the sacral pad exerts a force on the posterior aspect of the pelvis the child is still able to move foward away from the pad returning to the slumped posture with the pelvis posteriorly rotated. A pelvic strap pulling back and down at 45° is an essential component of any seating system but is not the solution to this particular problem. The main purposes of the strap are to prevent the child "standing" or extending up and out of the seat and for safety purposes in a wheelchair or vehicle. The solution lies in the application of an equal and opposite force on the pelvis to that exerted by the sacral pad and this is achieved through correct use of the kneeblock.

The force applied to the pelvis by the sacral pad is not equal throughout the length of the sacral spine but is at a maximum at the top of the pad where most force is required on the posterior, superior iliac spines to prevent posterior tilting of the pelvis. The kneeblock, when correctly adjusted and used with correctly positioned feet and ramped cushion, applies a force to the pelvis via the femurs and the hip joints. The hip joints lie below the level of the L5/S1 joint and thereby below the level of the top of the sacral pad. Accordingly, the force of the sacral pad and the force of the kneeblock applied equally and in opposite directions serve to rotate the pelvis forward from the posteriorly tilted position towards the neutral position. As the pelvis moves

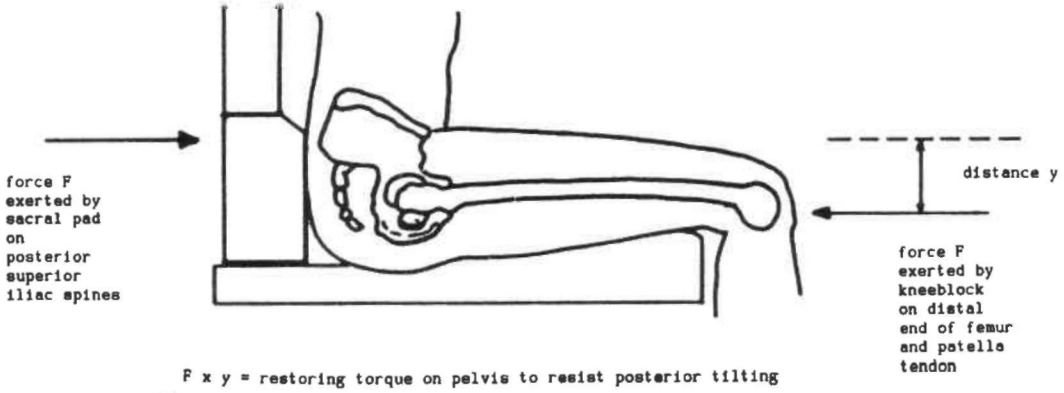


Fig. 5. Forces applied to the pelvis by the sacral pad and the kneeblock and the distance between them, y, producing the torque to hold the pelvis in the neutral position.

towards the neutral position so the distance between the line of action of the two forces is increased (Fig. 5). The forces applied to the child by the sacral pad and the kneeblock are therefore at a minimum when the pelvis is in the neutral plane and increase to a maximum, possibly intolerable level if the adjustment is incorrect and a slumped posture is allowed.

The correct application of these biomechanical principles is embodied in the design of the Chailey Adaptaseat and its successor the CAPS II. The essential feature of both designs is the easy adjustment of the components to achieve the desired result. If adjustment is not possible or cannot be carried out quickly and easily without workshop facilities and whilst the child is sitting in the seat, then the seating system is unlikely to provide ongoing postural control and the initial gains in ability will not be maintained. Once the postural stability has been achieved using these biomechanical principles, the trunk and head support required are often less than expected. After a short period of use the headrest can often be dispensed with and then only used for safety when travelling or perhaps when eating. As a child's abilities are consolidated and improve so the lateral supports can be adjusted to reduce the control provided allowing the child to be more active in the seat. The control and stabilisation provided by the correctly adjusted base of the seat allows dissociation of upper trunk movement and the lateral supports become limit stops. Thus static seating permits a dynamic child to remain dynamic but in a controlled manner such that he can regain his correct posture through the stabilisation of the base of support.

The kneeblock arrangement can also be used to correct or control a "windswept" posture (Fig. 6) by pushing back on the femur of the previously abducted hip and derotating the pelvis against the sacral pad. The other hip is then adducted to reduce the risk of dislocation. No force is applied along the femur of the previously adducted hip, i.e. the one in danger of dislocating or already dislocated. A gap between the kneeblock pad and knee ensures this.

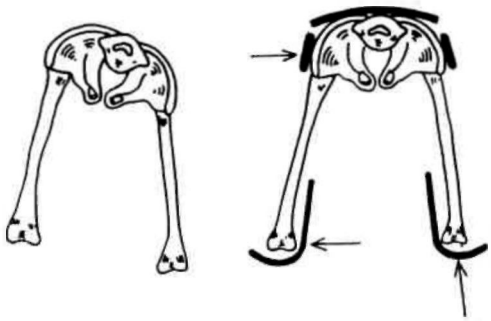


Fig. 6. Control and correction of the windswept hip posture by means of the sacral pad, kneeblock and lateral pelvic pads.

Development of sitting ability

The ability to sit unsupported develops in the normal child as part of the sequence of motor development of lying, sitting, standing, walking and running. This developmental sequence involves a mixture of neurological postural reactions and changes in the biomechanics of the spine, shoulder and pelvic girdles. At birth the majority of normal full term babies are able to anchor their bottoms when they are pulled from lying supine into a long sitting position. Head control during the manoeuvre is poor, the baby being unable to stop his head falling backwards as he is pulled up into a sitting position.

Motor development during infancy has long been described as occurring in a cephalocaudal direction, that is head control is noticeable first in the developmental sequence, followed by improvement in trunk control seen in sitting and total body control seen in standing. However this head to toe progression is an illusion. In fact all parts of the infant's body can be seen to be developing control simultaneously throughout infancy (Prechtl, 1984; Pountney *et al.*, 1990).

Motor development in infancy may be assessed in two complementary ways; assessment of neurological development and assessment of motor ability.

Assessment of neurological development

Neurological assessment of the infant consists of observation of the infant, and assessment of early automatic responses and reflexes such as the Moro response, asymmetrical and symmetrical tonic neck reflexes, with the righting and equilibrium reactions. Further details may be obtained from Baird and Gordon (1983). Neurological assessment requires skill and experience, is dependent upon the "state" of the child as defined by Prechtl (1974), and still has a considerable level of inter-examiner variability.

Assessment of motor ability

An alternative method is to use an observational approach to determine the highest level of ability a child can demonstrate in his normal environment. The child may adopt a lower level of postural ability to achieve a stable base for functional activity. A scale of levels of lying ability (Table 1) (Pountney *et al.*, 1990) and of sitting ability (Table 2) (Mulcahy *et al.*, 1988) have been described. These levels of ability may be used when describing the normal infant as well

Table 1. Levels of lying ability.

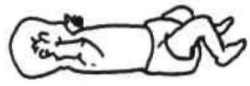
Supine

Level 1

Unable to maintain supine when placed except momentarily and then very asymmetrically. Rolls into and maintains side lying — body following head turning in a total body movement. Weightbearing through lateral aspect of head, trunk and thigh. Neck extended with chin poke.

Level 2

Settles on back when placed. 'Top heavy'. Weightbearing through upper trunk, head. Pelvis tilted posteriorly. Shoulder girdle retracted. Asymmetrical posture — head to one side, difficulty in turning it side-to-side — bottom moves laterally as the head is turned giving 'corkscrew' appearance.



Level 3

Maintains supine position with neutral pelvic tilt, hip abduction, shoulder girdle neutral. Symmetrical posture but 'top heavy'. Chin tucked, not retracted — head in midline and able to move freely side-to-side without lateral movement of bottom. Able to track visually and make eye contact. Weightbearing through pelvis and shoulder girdle giving general curvature to trunk — with 'pot belly' lateral profile. Beginning of unilateral grasp to side of body and takes fists and objects to mouth. May roll into prone due to lack of lateral weight shift.

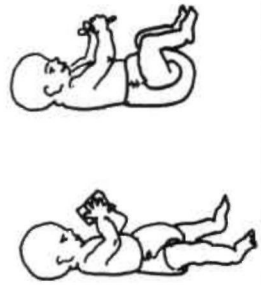
Level 4

Symmetry of posture and movement is first seen at this level. Pelvis anteriorly tilted, shoulder girdle protracted. Shoulders flexing and adducting allowing midline play above chest with hands together and feet together. Symmetrical posture. Weightbearing through upper trunk and pelvis. Definite lordotic curve. Chin retracted. 'Free' pelvic movement beginning, allowing child to touch knees with flexed hips (but not toes). Alternatively can extend hips and knees; rests in crook lying.

Beginning of lateral weight shift.

Beginning unilateral leg raise — independence of limbs from trunk.

Adept finger movements towards end of this stage.



Level 5

'Free' movement of shoulder girdle and pelvis on trunk. Pelvis has full range of movement allowing child to play with toes with legs extended and rolls into side lying. Side lying functional. Can return to supine. Weightbearing either on shoulder girdle and pelvis or central trunk only and playing between these postures. Efficient limb movement — hand play and prehensile feet — crossing midline.

Level 6

Pelvic and shoulder girdle moving freely. Consistent ability to roll into prone by achieving side lying as in level 5 and then anteriorly tilting pelvis on trunk and extending hips.

Prone

Level 1

'Top heavy'. Weightbearing through chest, shoulders and face. Pelvis posteriorly tilted. Hips and knees flexed. Shoulder girdle retracted, shoulders flexed and adducted. Asymmetrical posture and head to one side.

Level 2

Settles when placed. More generalised weightbearing than level 1. Weightbearing through chest, upper abdomen. Pelvis posteriorly tilted. Shoulder girdle retracted, shoulders flexed and adducted. Head to one side but beginning to lift it from floor with 'flat back' profile but not sustaining. Asymmetrical posture, bottom moving laterally as head turns side-to-side.

Level 3

Maintains prone position with neutral pelvis, shoulder girdle beginning to protract. Symmetrical weightbearing through abdomen, lower chest and knees and thighs. Maintains head lift from floor with total trunk curvature — head in line with spine. Rocking antero-posteriorly. No lateral weight shift and therefore often topples into supine as lifts head and chest up.

Level 4

Pelvis anteriorly tilted but not 'anchoring'. Shoulder girdle protracted, weightbearing through abdomen and thighs, varying between forearm and hand propping with shoulders elevated. Head and upper trunk movement dissociated from lower trunk allowing lateral trunk flexion with lateral weight shift = a beginning of pivoting. Angular lateral profile of upper chest and bottom. Unilateral leg kicking. Hand and foot play is midline.

Level 5

Pelvis anteriorly tilted. Shoulder girdle protracted — hand propping with extended elbows and lumbar spine extension. Weightbearing through iliac crests and thighs and lower abdomen. Pelvic anchoring and upper body movement (extension and rotation) upon it. Deft pivoting with lateral trunk flexion and moving backwards on floor. Purposeful roll prone into supine.

Level 6

'Free' movement of pelvis and shoulder girdle. Beginning to weight-bear on all fours/antero-posterior, rocking on all fours.

Reproduced by kind permission of the Editor from Pountney, T. E., Mulcahy, C., Green, E. (1990). Early development of postural control. *Physiotherapy*, **76 (12),** 799–802.

as those with a postural impairment, as seen in cerebral palsy and diseases with neurological degeneration or neurological injury. A definite link has been observed between a child's lying ability and his sitting ability. It has been found that a child has to achieve level 4 lying ability in both prone and supine positions before he can achieve level 3 sitting ability, i.e. maintaining independent sitting. In addition level 5 lying ability is achieved before level 5 sitting ability, i.e. maintaining sitting and moving out from his base (Pountney *et al.*, 1990).

Table 2. Levels of sitting ability.

When placed on a flat box, feet on the floor:-		
1. UNPLACEABLE	A child who wriggles & slides and cannot be placed in a sitting position.	
2. PLACEABLE, NOT ABLE TO MAINTAIN	A child who can be placed in a sitting position but needs holding to stay in position - at best he can balance momentarily.	
3. ABLE TO MAINTAIN POSITION BUT NOT MOVE	A child who when placed in a sitting position can just keep his balance as long as he does not move.	
4. ABLE TO MAINTAIN POSITION AND MOVE WITHIN BASE	A child who once placed in a sitting position can sit independently and can move his trunk forward over his sitting base but cannot recover his balance after reaching to one side.	
5. ABLE TO MAINTAIN POSITION AND MOVE OUTSIDE BASE	A child who can sit independently, can use either hand freely to the side of his body and can recover balance after leaning or falling to either side.	
6. ABLE TO MOVE OUT OF POSITION	A child who can sit independently and can transfer weight across the surface of a seat but cannot regain a correct sitting position.	
7. ABLE TO ATTAIN POSITION	A child who can regain his sitting position after moving out of it.	

Reproduced by kind permission of the Editor from Mulcahy, C. M., Pountney, T. E., Nelham, R. L., Green, E. M., Billington, G. D. (1988). Adaptive seating for motor handicap: problems, a solution, assessment and prescription. *Br. J. Occup. Ther.*, **51 (10)**, 347–352.

Assessment of postural ability and for postural support requirements

The assessment process is a comprehensive one which considers the whole child, his family, the home environment, the school environment, modes of travel, mobility and daily living issues. The assessment should define both treatment and complementary equipment needs in all postures. The complexitites and importance of correctly designed equipment, especially adaptive seating, and the need for compromise necessitates that everyone involved with the child, i.e. parents, carers, therapists, doctor, rehabilitation engineering personnel, teachers, nurses, etc., has to become involved or at least have an input to the process. It is also important that they realise that whilst the child is learning a new posture, finer activities such as those used for eating or for driving a powered chair or operating a computer, may deteriorate. This is especially so if a child has been using obligatory patterns of movement associated with an asymmetrical posture with inadequate stabilisation and control. The child will require both physical and mental support as well as re-education of these skills once a symmetrical posture with stability and control has been achieved. All those involved with the child have to understand this in order to provide the support the child needs. Progress in relearning the lost skills will result if the process is fully understood. Communication is therefore an extremely important and probably the most time consuming aspect of the assessment procedure often taking on an educational emphasis. Without communication, a great deal of effort and expensive equipment may be wasted.

The assessment therefore has the following main objectives:

(a) to identify and record a child's abilities in different postures and provide a means of improving these through treatment and provision of appropriate equipment;

(b) to identify and measure where possible any postural deformity and further define the equipment required, especially adaptive seating, to control and, if possible, improve these deformities and to prevent progression to fixed deformity;

(c) to establish and record a baseline of measures and abilities as a reference for subsequent reviews and assessments and as a means whereby the performance of the treatment and equipment can be monitored, e.g. the child's ability in an adaptive seating system should be measurably better than with no postural support;

(d) to communicate with and, where appropriate, educate all those involved with the child in the aims and objectives of the treatment and equipment, the details of the use of the equipment and the expected outcomes both positive and negative;

(e) to achieve agreement by all to the most practical solution(s) to the problems being addressed and to encourage participation in the attainment of the child's potential.

Assessment procedure

The procedure by which the assessment is undertaken is divided into three stages which are fully documented with both written and photographic records to include measurable data.

1) The child is observed and, preferably, photographed in his current seat or wheelchair. The reasons for requiring a new seat are established together with how the child is currently growing and any consequential changes in ability. The way in which the child uses his existing posture to eat, operate his wheelchair and/or computer and whether any obligatory patterns of movement are being used that may need re-educating are all observed and noted.

2) The seat or wheelchair is examined after the child has been removed or has transferred to another surface. This can provide information about how the existing seat or wheelchair is used by the tell-tale areas of wear or permanent depression or even breakage in extreme cases. It can focus attention on particular problems to be taken into consideration. It also allows the transfer procedure to be observed and assessed.

3) The child's abilities are established in different postures without support. This is the most important stage of the assessment which begins with the observations of how easily the child is to handle and an assessment of the contribution that the existing seat or wheelchair has made to a pattern of movement, i.e. has the seat contributed to an extensor pattern of movement or an asymmetric posture?

The child's abilities are then established:

(a) in the positions of lying supine, lying prone and side-lying,
(b) during the pull to sit,
(c) in long sitting,
(d) sitting on a flat box,
(e) sitting on a ramped cushion, and
(f) standing.

In each of these positions or manoeuvres observations are made on the following:

(i) how symmetrical the child is and how he distributes weight and anchors himself on the support surfaces,

(ii) how the child orientates body segments, i.e. is the pelvis posteriorly or anteriorly tilted? is the

spine extended or flexed? is the shoulder girdle protracted or retracted? how does the child position or make use of head and arms?

(iii) the ability the child has to conform to positions, maintain positions, move within positions and move into and out of positions all with minimum or zero assistance and support,

(iv) the degree of postural or fixed deformity or contractures present or the potential for developing any.

Whilst the child is sitting on the ramped cushion, the support required to improve his abilities is simulated by hand and the effect of doing this is noted.

Lying in the supine, prone and side lying positions

The child's level of lying ability is assessed by observing the child in the prone and supine positions. The symmetry or asymmetry of posture, anteroposterior tilt of the pelvis, retraction or protraction of the shoulder girdle and the areas of the body used to weight bear in these positions are assessed and noted. The child's ability to move within the posture and into and out of the posture are also assessed together with the functional ability. From these observations the level of lying ability of the child is determined. This will indicate the problems the child is likely to have in the sitting posture, e.g. children with lying ability below level 4 will not achieve level 3 sitting ability. Also, poor pelvic and truck control will be indicative of the child's difficulties in organising his body and in weight bearing adequately through his bottom and thighs in the sitting posture.

During the assessment, the child's pelvis is placed into a neutral position and the effect of this on the child's ability to align or position his head, truck, shoulder girdle and limbs is observed and noted. The pelvis and trunk are then organised into alignment and the effect of this on the child's movement of head, shoulder girdle and limbs is noted.

Thus a complete picture of the child's abilities in the lying position is obtained together with an indication of problems likely to be encountered in the sitting posture.

Pull to sit

The child is pulled by his hands from the supine position towards a long sitting position. The child's ability to dissociate his trunk movement from the lower part of his body is assessed and noted. This is reflected in the child's ability to anchor his bottom on the support surface and flex at the hip joints. If the child is able to do this then he should be at least placeable in the sitting position, i.e. at least level 2 sitting ability. If the child cannot anchor his bottom and instead slides along the surface and generally curves his body forwards with little or no hip flexion, i.e. his body behaves as one single structure, then he is likely to be unplaceable, i.e. level 1 sitting ability.

Long sitting

The long sitting position is often difficult to achieve or maintain but it is an important position because it emphasises any contractures or tendencies towards deformity that may not be apparent in other positions. The hamstrings, spine, hips, knees and ankles are examined to establish whether they will physically prevent the child from attaining the upright sitting posture. The importance of emphasising these problems is that treatment and postural control equipment can be defined to correct these tendencies. For example, an internally rotated and adducted hip leading to pelvic obliquity will also result in postural scoliosis. The scoliosis could be the focus of attention but by simply abducting and externally rotating the hip, the pelvic obliquity can often be eliminated and the scoliosis corrected. Naturally, if the adductor muscles are too tight, the problem has to be remedied by therapy before the postural equipment can be supplied to maintain the corrected posture. In extreme cases, surgery may be required and then therapy and the appropriate equipment during the post-operative period are essential to maintain the surgical correction. A rigorous assessment of need in the long sitting position is therefore just as important as, if not more so than, the remainder of the sitting positions.

Sitting on a flat box

The height of the assessment boxes is adjusted such that the child can sit with thighs supported throughout their length on the surface of the box and the feet flat on the floor. The ease with which the child can be placed on the box is noted. The child's ability to maintain the sitting position with minimum or no support is noted. The symmetry of the child's posture anteroposteriorly as well as laterally is assessed and noted. The child's level of sitting ability is determined whilst he is sitting on a flat box.

Sitting on a ramped cushion

The height of the assessment boxes is readjusted to allow the child to sit on the ramped cushion on top of the boxes with his thighs supported throughout their length on the ramp, his femurs horizontal and feet flat on the floor. The child's ischial tuberosities should be supported on the flat, horizontal section of the

cushion. The effect of the ramped cushion is to improve the child's sitting ability and bring the upper body forward over the sitting base.

The symmetry of the child's posture both anteroposteriorly and laterally is assessed and the effect of the cushion on the child's ability to maintain the sitting posture and move within it is noted.

Standing

When considering prescriptive seating systems it is important to know whether the child can assist with transfers to the standing posture or even transfer independently. The height of the seating system may be important and the ease with which the child can move footplates and other components out of the way has to be assessed.

First, the child's ability to move across the cushion and to stand up is assessed. His ability to lean forwards and sideways whilst on the cushion will give an indication of the ease with which he should be able to move the seat and wheelchair components. The type and amount of support required for these manoeuvres has to be assessed and it may be different from that required for other functions in the sitting position. Compromise or easily adjustable support may be required.

Prescription

A baseline level of achievement and needs are recorded for each child, both for treatment and for postural support sufficient to maintain his abilities throughout the day. Hare's work (Hallett *et al.*, 1987) has been extremely useful and an adaptation of her classification led to the description of seven levels of sitting ability (Table 2). These levels describe the ease with which a child can be placed in a sitting posture, how he anchors his bottom in a sitting posture and how well he can ajdust his body over and out of his sitting base. The prescription of seats follows from the information gained from assessment of sitting ability.

Children with sitting ability from level 1 to 3 have poor postural ability. Without seating support they remain physically dependent and often are unable to observe what is happening around them. Seating systems incorporating the biomechanical principles described above to achieve the upright posture are essential. Full postural stabilisation and an improved functional ability can be achieved leading to improvement in postural ability. In addition, it is particularly important to adjust the environment around the child whilst he is in the seating system. For example, the schoolwork, the television or the computer and monitor must be positioned to allow for the child's line of vision compatible with the current and expected abilities.

Children with greater postural ability, that is, level 4 and above, require postural stability to encourage independence. Seating systems which incorporate the biomechanical principles described above but with reduced trunk support will allow both work and rest positions for the child. The dimensions of the seat cushion and sacral pad are crucial as incorrect sizes, for example excessive length, may induce sacral sitting. The cushion requires securing, as a sliding cushion can also induce a sacral sitting position. The consideration of work heights must not be forgotten.

Sitting ability level 1

Even if the child cannot be placed in a sitting posture, this is still recorded as a positive level of ability because it defines a major need for treatment and postural support. At this ability level a child cannot achieve or maintain a sitting posture, that is he cannot anchor his pelvis or dissociate the movement of his trunk from his lower body. Prescriptive seating is required to provide postural fixation, especially stabilisation of the pelvis. The biomechanical principles described above will achieve this.

An upright position must be introduced as early as possible to reduce the de-stabilizing effect of a posteriorly tilted posture. If the child remains at this low level of ability, he will become increasingly difficult to handle particularly as he approaches adolescence. When increased tone and primitive reflexes compound the postural instability in the tilted position, the child may become "unmanageable". It is therefore important that the child experiences frequent handling and changes of position if he is going to be able to improve his postural ability. Posture is dynamic, and consideration of alternative ways of introducing upright posture with symmetrical weight bearing should be undertaken. Pope (1988) has successfully simulated the posture adopted by motorcyclists in an adult population of low postural ability. The pelvis is stabilised by using a scooter saddle with knee support and the trunk supported forwards over the base. Stewart and McQuilton (1989) have also shown preference for this type of posture for the lower ability child. A useful alternative seating support can be provided by the Controller Chair (Stowaway Furniture and Design Ltd, Bedford) particularly as its components can be varied to offer comfortable and corrective support in the lying position. If a child cannot take weight through his pelvis in the lying position, he will not become placeable and manageable in the sitting position.

Sitting ability level 2

In order to maintain an upright sitting posture, a child at level 2 ability needs a very supportive seat with the full biomechanical principles described above. The seat base must be horizontal. The child may be helped to learn to maintain an upright posture by providing a variable trunk support, including a narrow anterior support pad which will not impede protraction of the shoulder girdle.

Lateral trunk support should align with the chest contours, an anterior thoracic strap giving alternative or additional trunk security if necessary. Stabilisation of the shoulder girdle can be encouraged by using the anterior support pad with a tray at elbow height. This posture can be assisted by arm gaiters especially constructed to hold the elbows flexed for arm propping on the tray surface.

Sitting ability level 3

It must be remembered that a child at sitting level 3 is dependent on his hands for support or will only be able to adopt a fixed position unless he is given adequate support to enable him to participate in life. A stable, symmetrical sitting base needs to be provided as described in the biomechanical principles.

The child should be able to regain an upright sitting position, after leaning forwards, the seating system lateral supports being spaced and shaped appropriately to facilitate this. Variations of postural support should be made throughout the day, such as limiting the use of a headrest to travel in a vehicle or a power chair or adjusting the lateral supports to encourage lateral trunk movements.

Sitting ability level 4

Children with a greater ability, that is level 4 sitting ability and above, require postural stability using the biomechanical principles for the upright posture to encourage independence. In this way a child is able to work, rest and play. The dimensions of the seat cushion and sacral pad continue to be crucial as incorrect sizes may induce sacral sitting. The cushion must be secured as a sliding cushion reduces postural stability by inducing a sacral sitting posture. An appropriate work height should be arranged.

At sitting ability level 4, the child still has an immature rounded spinal posture, and lacks adequate pelvic stability upon which to adjust his trunk and raise his arms to shoulder level. He is not able to counterpoise efficiently and, in order to reach out to one side, he will either reach forward and down, or may alternatively adjust his entire sitting base by swinging his legs to one side, so that his outstretched arm does not extend far beyond his sitting base.

The most important feature of prescriptive seating for level 4 ability is a stable sitting base upon which he feels secure enough to achieve a straight back posture and the ability to reach out from his seating base. It may be necessary to add a pommel following the contours of the thighs in order to widen the sitting base and perhaps a kneeblock if asymmetry is predominant. Anterior thoracic support should not be necessary for this child but he will need some lateral control, such as armrests. These can be removed as soon as the child becomes more able.

Sitting ability level 5

Stability of the child's sitting base must be provided, with an orthogonal base (horizontal ramp cushion and probably a sacral pad). His feet should be on the floor when sitting on a school chair or reach the floor from a wheelchair if possible, to encourage him to reach further from his base and eventually acquire the ability to transfer out of his seat. His independence skills will depend to some extent on both a correct sitting height and a correct working height.

A child at level 5 sitting ability will probably find it easier to counterpoise to one side than the other and may initially need lateral support to allow side propping to either side or a pommel as described in level 4. Armrests should be removeable, but can help to boost a child's security when he is mobile in his seat, such as when he is driving a power chair or being pushed in a manual wheelchair, and may help with transfers.

Sitting ability level 6

A child who can get out of his seat by adjusting his trunk weight sideways or forwards over his sitting base will need a stable sitting base upon which he can develop a more mature sitting posture and from which he can transfer. An orthogonal base as described above can provide this. His feet should be on the floor to help with transfers. Desk height should be appropriate for his visual and manual abilities as well as to assist him reaching out of base and transferring. The child needs to be able to undo any security straps himself, such as the pelvic strap, if he is to maintain his independence in transferring.

Sitting ability level 7

Although a child at this level of ability can sit he is probably still learning to walk. His independence may still depend on the height and depth of his seat and on his work height. A stable seat with a rest position is required. He will need to be able to fasten and release his straps.

Non right-angled postures

For the more able child, therapists may wish to try out seating solutions that have been developed for people suffering from back pain, such as forward sloping seats with or without knee pads. It is important to remember that people with normal ability can adopt an upright posture and lordosis. To provide a similar solution for the child with sitting ability level 7, it is necessary to maintain his ability to get into his seat himself. The seat may, therefore, require modification.

This type of seat, when used for physically handicapped children will only facilitate the correct spinal posture if the child has the physical ability to attain it. It does not induce a lordotic posture if the child has not yet developed it.

Monitoring seat performance

It is necessary to monitor the effect of the seat on the child's ability and to check that his sitting ability remains better in the seat than out of it. As the child's pelvis changes to a neutral position, the seat length required will reduce. If the seat is not shortened, the excessive seat length will permit a sacral sitting posture to remain with consequent loss of potential for further improvement. The child may require additional support during some activities, for example, driving his power chair, in order to assist his postural adjustment to the movement of the chair and of the joystick. At other times, reduced support may provide an opportunity for the child to contribute actively to his postural control.

A permanent record of the child's achievement can be made by documentation of the child's lying ability and sitting ability in and out of the seat, and by using polaroid pictures and video.

Loss of sitting ability

If a child apparently loses sitting ability, it is important to check whether this is a genuine loss of ability or one provoked by poor positioning, such as a tilted or reclining seating system or maladjusted seating system.

Genuine loss of physical ability

This may be present in degenerative disorders of the nervous system and of the muscles. If sitting ability is becoming less for these reasons, it is essential that a balanced seating posture is maintained from the outset as the effects of gravity on a weak system cause severe postural deformity. Whilst it is important to allow the full possible range of free movement, postural stability may be maintained by providing an outer limit of movement for the trunk and stability for the pelvis. An example of this is in boys with muscular dystrophy whose function is often achieved by trunk movement so that intimate support would reduce function. Carefully positioned lateral supports may permit enough lateral movement to maintain function while still preventing excessive lateral lean.

Tilted or reclined postures

It has been shown by Nwaobi (1986) with EMG studies that both hip extensors and hip adductors exhibit a significant increase in tone when the child is reclined or tilted from an upright posture, thus promoting extensor thrust. In addition, in a reclined position, the child's hands become positioned in "high guard" and are not in a practicable position for use. Nwaobi (1987) has demonstrated that upper extremity function is not maximised in the reclined position.

Children with motor handicap who are placed in a reclined or tilted position feel that they are falling and often try to counteract this feeling by trying to come forward. This is often interpreted as flopping forwards so that the child is given further restraints and/or reclined further in an attempt to correct this (Hare, 1988). For people with poor protective reactions, backward or reclined positioning is not preceived as a position of comfort (Motloch, 1977).

The reclined or tilted posture is not a functional position for vision. Either the line of vision is upwards towards the sky or ceiling, or the person has to continually lift his head forward from the reclined position – a difficult manoeuvre – in order to see.

Eating and drinking skills are best established and maintained in an upright position. Swallowing is neurologically a flexor activity. Laryngeal elevation during normal swallow requires generation of adequate shortening of the muscles above the larynx with some simultaneous lengthening of muscles below the larynx. An increase in tension in the lower group such as when the neck is extended, increases difficulty in swallowing. Flexing the neck, on the other hand, facilitates laryngeal elevation by decreased length and tension of the lower group of muscles. In addition, a reclined position increases the risk of choking because anatomical closure of the larynx may not occur during swallowing.

An investigation into the effect of orientation on the cognitive ability of children with cerebral palsy shows that while the tilted seated position had no effect on simple perceptual tasks, complex tasks involving inter-system processing were significantly worse when the children were in a correctly fitted seat tilted backwards by 20° than when they were in a wheelchair alone. The children performed best when correctly seated in an upright sitting position (Green, 1987).

Normal infants develop their ability to recover sitting balance from a forward prop position before developing the ability to side prop and then returning to a balanced sitting position from a reclined position (Illingworth, 1975). It is therefore a developmentally later ability to learn to sit forward from a reclined position, than to learn to sit forward in a propped position.

Deformity

Increasing deformity even to a small extent may compromise sitting balance. An early windswept deformity of the pelvis with pelvic tilt may reduce the area of the sitting base, and change the forces of gravity acting on the body. Asymmetrical forces may potentiate scoliosis, increasing deformity and loss of sitting balance. Increasing posterior tilt of the pelvis may lead to loss of the usual spinal curves of the mature posture, and loss of a balanced sitting position. The individual may eventually take up the C-shape within the chair or an extended position with the head extended backwards over the back of the chair (Pope, 1985).

Growth

An increase in the length of the trunk may lead to changes of forces acting on the shoulder and pelvic girdles, compromising sitting balance. Femoral growth leads to an increased seat depth requirement. If seat depth is not adjusted with growth, the reduced support the thighs and control of the pelvis in sitting may lead to reduction in sitting ability.

Maladjustment of the seat

A poorly adjusted seat or a seat requiring adjustment for growth or changes in ability can reduce a child's sitting ability or his potential for improvement. Regular checks of adjustment must be made even if no further growth is expected.

Conclusions

Seating must contribute actively to encourage a child's postural development. It should allow the child to be dynamic and permit a higher level of sitting ability than the child exhibits out of the seat. The seat must also continue to complement both treatment principles and the child's abilities as these improve. Seating is part of postural management in all postures and postural management must be considered as part of the child's overall management programme.

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REFERENCES

BAIRD, M. W., GORDON., E. C. (1983). Neurological evaluation of infants and children. Clinics in developmental medicine. — Oxford: SIMP, Blackwell Scientific.

GREEN, E. M. (1987). The effect of seating position on cognitive function in children with cerebral palsy: 59th Annual Meeting of British Paediatric Association (Abstract G158). — London: The Association, p108.

HALLETT, R., HARE, N., MILNER, A. D. (1987). Description and evaluation of an assessment form. *Physiotherapy*, **73**, 220–225.

HARE, N. (1988). Children keep you thinking, interview with Dorothy Henham. *Therapy Weekly*, March 24, 6.

ILLINGWORTH, R. S. (1975). The development of the infant and young child, normal and abnormal/6th edition. — Edinburgh: Churchill Livingstone.

MOTLOCH, W. M. (1977). Seating and positioning for the physically impaired. *Orthot. Prosthet.*, **31 (2)**, 11–21.

MULCAHY, C. M. (1986). An approach to the assessment of sitting ability for the prescription of seating. *Br. J. Occup. Ther.*, **49**, 367–368.

MULCAHY, C. M., POUNTNEY, T. E. (1986). The sacral pad — description of its clinical use in seating. *Physiotherapy*, **72**, 473–474.

MULCAHY, C. M., POUNTNEY, T. E. (1987). Ramped cushion. *Br. J. Occup. Ther.*, **50**, 97.

NWAOBI, O. M. (1986). Effects of body orientation in space on tonic muscle activity of patients with cerebral palsy. *Dev. Med. Child Neurol.*, **28**, 41–44.

NWAOBI, O. M. (1987). Seating orientations and upper extremity function in children with cerebral palsy. *Phys. Ther.*, **67**, 1029–1212.

POPE, P. M. (1985). A study of instability in relation to posture in the wheelchair. *Physiotherapy*, **71**, 124–129.

Pope, P. M., Booth, E., Gosling, F. (1988). The development of alternative seating and mobility systems. *Physiotherapy Practice*, **4**, 78–93.

Pountney, T. E., Mulcahy, C., Green, E. (1990). Early development of postural control. *Physiotherapy*, **76**, 799–802.

Prechtl, H. R. F. (1974). The behavioural states of the newborn infant: a review. *Brain Res.*, **76**, 185–212.

Prechtl, H. R. F. (1984). Continuity and change in early neural development. In: Continuity of neural functions from prenatal to postnatal life. Ed. H. R. F. Prechtl. Clinics in Developmental Medicine, 94. – Oxford: SIMP, Blackwell Scientific, p1–15.

Stewart, P. C., McQuilton, G. (1987). Straddle seating for the cerebral palsied child. *Physiotherapy*, **73**, 204–206.